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14. ABSTRACT
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Abstract

Clinical data show that there is a strong correlation between the cosmetic outcome of women with early stage breast cancers treated with MSB applicator and the spacing between the MammoSite balloon surface and the skin. Many women are not able to take advantage of MSB because of inadequate balloon-to-skin distances. The implementation of a thin customizable shielding layer to the MammoSite procedure will allow dynamic control over the skin dose overlying the MammoSite balloon. Dose distribution may be monitored using a combination of methods that includes usage of a gamma camera detector system and scintillating fiber technology. Jefferson Lab's upgraded gamma camera system for BSGI may be used for imaging and dosimetric studies during IB. It will allow in real time verifying that breast skin dose does not exceed the safety limits during the shielded MSB and hence also the shielding powder placement in the balloon implanted breast (phantom). The objective of this project is to develop innovative techniques and advanced technologies surround the IB methodology to facilitate more women taking advantage of APBI and therefore also of BCT to reduce breast cancer recurrence and increase survival expectancy. HU faculty and students will be integrally involved in research to advance breast cancer treatment and improve patient outcomes collaborating with a national lab and a medical school gaining hands-on experience in moving technology form bench to bedside while building capabilities at HU to successfully compete for and conduct breast cancer research.

Development of a Hampton University Program for Novel Breast Cancer Imaging and Therapy Research

Introduction

Hampton University (HU) is a historically black college (HBCU) located on Virginia's tidewater peninsula, about 10 miles from the Thomas Jefferson National Accelerator Facility (Jefferson Lab) and about 8 miles from the NASA Langley Research Center. The HU Physics Department offers B.Sc, M.Sc, and PhD degrees in Physics with about 30 graduate students and 30 regular faculty in the department. This proposal will facilitate a collaborative research project with the research taking place largely at the nearby Thomas Jefferson National Accelerator Facility (Jefferson Lab or Jlab) initially, but later conveniently transferred to the HU Proton Therapy Institute (HUPTI). In the course of the collaboration, it is planned that HU researchers gain significant expertise in the high-end instrumentation-knowledge that will leveraged for future projects perhaps collaborative with Jlab and certainly competitive for mainstream funding support and sustainability research at the university.

The proposed project is an ideal choice for this model as it is crucially relevant for breast cancer care. It involves portable technology that can be initially developed at the Jlab site and then easily moved to and based at HUPTI. Strong clinical support is provided by EVMS, HUPTI. The close proximity of these three institutions with a history of working together ensures that HU researchers will have permanent access to resources otherwise inaccessible even to many large majority institutions. The Jlab resources include the detector and imaging group and laboratory an advanced machine shop staffed with expert technicians entire fast electronics and data acquisition groups and a scientific computing center. With this level of support nearby, the development of a breast cancer instrumentation center at HU has a strong probability for success.

Body

HU faculty training for breast cancer research will spend a minimum of two full days /week routinely in the first two years working side by side on the proposed research projects with Jlab scientists. The proposed project has been carefully chosen to provide a wide range of skill training and a crucial knowledge base- all directly applicable to the development of breast cancer research at Hampton

University. The project includes both diagnosis and treatment technologies, including: advanced imaging techniques, lesion localization, breast abnormality visualization, control and graphic software, surgical application and radiation oncology. Skills and expertise will be acquired in designing and building breast phantoms that allow the use of inflated brachytherapy applicator balloons to explore possible treatment protocols. HU personnel will also receive didactic instruction for usage of the microSelectron HDR High Dose Rate After loading System with an Ir-192 source for intracavitary brachytherapy procedures during laboratory pre-clinical imaging and dosimetry equipment testing, calibration and data processing, in collaboration with EVMS colleagues.

Mentees will obtain unique and transferable skills and expertise in: 1) novel approaches in advanced radiological modalities; 2) imaging system design and data acquisition software development for applications in nuclear medicine planar imaging and tomographic imaging; 3) electronics and detector instrumentation development; 4) breast phantom construction and implantation; 5) laboratory pre-clinical device testing calibration and data processing; 6) treatment planning algorithm development for intracavitary brachytherapy (IB); and 7) dose calculation approaches through image analysis

Key Research Accomplishments

Change in PI (from Keppel to Kenney) January 1, 2013

Aim 1 Evaluate the optimal powder arrangement, material and amount that are practical for reducing the skin dose. Data for detailed studies will be obtained utilizing relatively simple and equipment and precision Monte Carlo simulations.

Aim 2 Develop and test a practical method for application of a magnetic field for shield shaping. The method must be reproducible and provide the desired placement of shielding powders in the MammoSite balloon.

Aim 3 Develop an analytic model based on precision Monte Carlo simulations and laboratory data for determination of the required amount of powders to limit the skin dose to an optimal value deduced from several clinical trials.

Aim 4 Create an algorithm that uses the analytic model described in *Specific Aim 3* above, and provides as an output dose distribution in the treatment volume that is modified due to effect of the shielding. Modify an existing brachytherapy treatment planning program for MammoSite to incorporate this algorithm. Verify results with data.

Aim 5 Explore methods for determining the dose being delivered to the patient (breast phantom). Optimize dose monitoring via use of the gamma camera detector system, and scintillating fiber detector technology. Crosscheck these results against measurements with the MOSFET patient dose verification system to ensure accuracy and reproducibility.

1. **Starting January 1, 2013, this award supported postdoctoral fellow, Dr. Lingyan Zhu. She has finished the motion management/tracking research at the Hampton University Proton Therapy Institute and EVMS. This research directly supports HUPTI's irradiation research at HUPTI, and so is in keeping with the goals of the grant.**
2. **PhD candidate John Okine (Department of Physics) has finalized his thesis (summarized in the Annual report 2013) and has begun manuscript preparation. He will defend his thesis June 16, 2014.**

Aim 6 Bench implement the entire procedure including treatment planning, powder insertion in balloon in phantom, magnetic filed application external to phantom and resulting dose measurement.

Aim 7 HU, Jefferson Lab, EVMS has finalized the CRADA agreements and personnel will coordinate breast cancer specific technology development projects.

Reportable Outcomes

At EVMS: The subcontract was finally approved and signed by both parties September 2013. This project has provided an opportunity for HU researchers and students (see previous Annual report John Okine's PhD thesis overview 2013) to facilitate the development of an improved cancer imaging modality that could greatly improve patient care. Mr. Okine will receive his PhD in physics (Medical Physics emphasis) this summer June 2014.

HU/Jlab/Dilon
Negotiations are complete between Hampton Jlab and Dilon Technologies. All parties are awaiting approval for a no-cost extension and once approved, the JLab research project will begin. They will apply SiPM technology developed for nuclear physics to improve breast cancer detection. The research goal is to develop a low profile gamma camera that would be used for breast cancer detection.

At HU: Provide capabilities and equipment to form the basis for continued breast cancer research with possibilities for future sponsored research support. The project provided an opportunity for HU researchers and students to facilitate the development of an improved cancer imaging modality that could greatly improve patient care. The techniques and skills developed in working on this project formed the basis of a longer-term technology development or clinical implementation project, providing prototype data for future proposals and has expanded efforts throughout HUPTI.

At JLab: This project will further develop and expand JLab's detector and imaging expertise particularly in the area of gamma imaging for cancer detection. In particular JLab will gain experience applying its high speed digitization technology and the latest silicon photo- multiplier technology to non-nuclear physics applications.

At: Dilon: Allow Dilon to make use of technical expertise and resources in Jefferson Lab and HU to facilitate the development of a SiPM based gamma camera which would have improved ability to detector breast cancer tumors. Development could lead to attracting additional funding to support construction of a clinical device leading to a new product for Dilon.

Tasks:
The following activities have begun
Jefferson Lab Tasks: The JLab Radiation Detector and Imaging Group will oversee the design and construction of a silicon photomulti- plier (SiPM) based breast cancer detector, mentoring an HU researcher also working on the project, and assist with detector calibration and breast phantom measurements to quantify the detector performance.

1. SiPM Gamma Camera Development. Jefferson Lab will design and construct the electronics necessary to produce a gamma camera able to fit in an existing Dilon camera body.
2. EFADC-16 Electronics Interface. Jefferson Lab will design and build circuitry to allow interfacing the SiPM channels of the SiPM gamma camera allowing for digitization with the JLab EFADC-16 digitization module.
3. Data Interface Software Development. Jefferson Lab will develop an API for Ethernet communication with EFADC,-16 data format, and calibration information. Jefferson Lab will assist Dilon with integration of the detector data into the Dilon software.

4. System Evaluation. Jefferson Lab will assist HU and Dilon with detector characterization as well as phantom and clinical evaluation of the system.
5. Report/Documentation Generation. Assist with the generation of technical (mechanical, electrical and software) documentation by the collaborating team regarding the operation and use of the SiPM based gamma camera. Jefferson Lab will work with the collaboration on the preparation of publications regarding the use of the system.

Dilon: Dilon Technologies will be responsible for detector evaluation and integration to the Dilon software.

1.SiPM Gamma Camera Development. Dilon will assist Jefferson Lab with the design construction of the SiPM detector to allow integration into a Dion camera body.
2. Data Interface Software Development. Dilon will assist with the design and testing of the API for Ethernet communication with EFADC,-16 data format, COG and calibration information. Dilon with Jefferson Lab will integrate he detector data into the Dilon system.
3. System Evaluation. Dilon will assist Jefferson Lab with the determination of the response function including calibration procedure. Additionally, Dilon will assist Jefferson Lab with phantom and clinical evaluation of the system.
4. Report/Documentation Generation. Dilon will direct the generation of technical (mechanical, electrical and software) documentation by the collaborating team regarding the operation and use of the Jefferson Lab handheld gamma camera. Dilon will work with the collaboration on the preparation of publications regarding the use of the system. HU: HU will be responsible for coordinating testing and evaluation of the system.

System Evaluation. HU will assist Dilon and Jefferson Lab with the determination of the response function including calibration procedure, and with phantom and clinical evaluation of the system.

Scientific Analysis: HU will lead the analysis of the imaging results to quantify the performance comparison between the SiPM based detector and the Dilon 6800.

Report/Documentation Generation. HU will assist with the generation administrative and technical documentation by the collaborating team regarding the operation and use of the Jefferson Lab SiPM gamma camera. HU will work with Dilon and Jefferson Lab on the preparation of publications regarding the use of the system.

Conclusion

Thus far implementation of the subcontract to EVMS has been completed. HU faculty, Postdoc (Lingyan Zhu) and PhD candidates (John Okine) have been integrally involved in research to advance breast cancer treatment and imaging. Currently, we are awaiting for a no cost extension for the work between Hampton and Jlab, Dilon technologies to begin so work has not begun due to change in PIs and CRADA negotiations. All parties (HU, Jlab and Dilon) have agreed to commence work once the no cost extension has been accepted.